Chapter 14 Supplemental Questions

1. A German passenger airship, the Hindenburg, made its maiden voyage on March 4, 1936. Although the original design used helium as a lifting agent, it was replaced by the much less expensive and easily generated gas, hydrogen.

   a. Why might helium have been a better choice than hydrogen in the end? (Hint: what kind of element is helium?)

   Helium is an inert gas (noble gas). It is not flammable

   b. Because hydrogen was relatively cheap to generate, the hydrogen cells of the Hindenburg were filled to capacity before take-off. As the aircraft rose, would these cells need to be refilled or emptied to account for the change in altitude? Explain.

   The relationship between pressure and volume is inverse. At higher altitudes, pressure is lower. This change in pressure would cause the cells to increase in volume. If they were already at maximum capacity on the ground, the cells would need to be emptied as the hindenburg ascended.

   c. Hydrogen is generated by the electrolysis of water in the following reaction.

   $$2H_2O \rightarrow 2H_2 + O_2$$

   i. What type of reaction is this? Decomposition

   ii. What volume of water would be required to produce the 7 x 10^6 cubic feet of hydrogen that was used to fill the Hindenburg at STP? (Density of water is 1g/ml. $1cm^3$=1ml)

   $$7\times10^6 ft^3 \left(\frac{28317 cm^3}{1 ft^3}\right)\left(\frac{1L}{1000cm^3}\right)\left(\frac{1 mol H_2}{22.4L}\right)\left(\frac{1 mol H_2O}{1 mol H_2}\right)\left(\frac{18g}{1 mol H_2O}\right)\left(\frac{1mL}{1g}\right)\left(\frac{1L}{1000mL}\right) = 1.6\times10^5 L \approx 2\times10^5 L$$

   iii. If the maximum capacity of the Hindenburg's hydrogen cells was x 10^6 cubic feet at STP, how much hydrogen would have to be released from the cells when the Hindenburg rose to an altitude where the pressure was 40 kPa and the temperature -23°C to keep the Hindenburg from bursting.

   @ STP

   $P_1 = 101.3 Kpa$ $\quad P_2 = 40 Kpa$

   $V_1 = 2\times10^8 L$ $\quad V_2 = X$

   $T_1 = 273K$ $\quad T_2 = 250K$

   $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

   $$V_2 = \frac{P_1V_1T_2}{T_1P_2} \quad \frac{(101.3Kpa)(2\times10^8 L)(250K)}{(273K)(40Kpa)} = 4.6 \approx 5\times10^8$$

   Because the cells were at full capacity on the ground, any increase in volume would burst the cells so $5\times10^8 - 2\times10^8 = 3\times10^8 L$ would have to be expelled.

2. In humans and mammals, respiratory gas exchange occurs in the alveoli where oxygen is exchanged for carbon dioxide. The mechanism by which this occurs is diffusion.

   a. Which gas would you expect to diffuse more quickly during this exchange? Explain.

   $CO_2 = 44.01g$ $\quad O_2 = 32g$ due to its smaller molar mass, O_2 diffuses more quickly

   b. If air is comprised of 21% oxygen, 78% nitrogen, 0.04% carbon dioxide and insignificant amounts of a variety of other gases. What is the partial pressure of these gases at under standard atmospheric conditions? (provide your answers in kPa)

   atmospheric pressure in Kpa = 101.3 Kpa = P_{Total}

   $(101.3 \times 0.21) + (101.3 \times 0.78) + (101.3 \times 0.0004) = 100.3 Kpa$

   O_2: 21.27 Kpa + N_2: 79.01 Kpa + CO_2: 0.04052 Kpa

   other gases = 1 Kpa

Boyle's Law $V_1P_1 = V_2P_2$

1) If I have 5.6 liters of gas in a piston at a pressure of 1.5 atm and compress the gas until its volume is 4.8 L, what will the new pressure inside the piston be?

$V_1P_1 = V_2P_2$ $P_2 = \frac{V_1P_1}{V_2}$ $\frac{(5.6L)(1.5atm)}{(4.8L)} = $ **1.8 atm**

$V_1 = 5.6L$ $V_2 = 4.8L$

$P_1 = 1.5atm$ $P_2 = X$

2) I have added 15 L of air to a balloon at sea level (1.0 atm). If I take the balloon with me to Denver, where the air pressure is 0.85 atm, what will the new volume of the balloon be?

$V_1 = 15L$ $V_2 = X$ $V_2 = \frac{V_1P_1}{P_2}$ $\frac{(15L)(1.0atm)}{(0.85atm)} = $ **18L**

$P_1 = 1.0atm$ $P_2 = 0.85atm$

3) I've got a car with an internal volume of 12,000 L. If I drive my car into the river and it implodes, what will be the volume of the gas when the pressure goes from 1.0 atm to 1.4 atm?

$V_1 = 12000L$ $V_2 = X$ $V_2 = \frac{P_1V_1}{P_2}$ $\frac{(1.0atm)(12000L)}{(1.4atm)} = $ **8.6×10^3 L**

$P_1 = 1.0$ $P_2 = 1.4$

Charles's Law $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

1) If I have 45 liters of helium in a balloon at 25^0 C and increase the temperature of the balloon to 55^0 C, what will the new volume of the balloon be?

$V_1 = 45L$ $V_2 = X$ $\frac{V_1T_2}{T_1} = V_2$ $\frac{(45L)(328K)}{(298K)} = $ **50. L**

$T_1 = 298K$ $T_2 = 328K$

2) Calcium carbonate decomposes at 1200^0 C to form carbon dioxide and calcium oxide. If 25 liters of carbon dioxide are collected at 1200^0 C, what will the volume of this gas be after it cools to 25^0 C?

$V_1 = 25L$ $V_2 = X$ $V_2 = \frac{V_1T_2}{T_1}$ $\frac{(25L)(298K)}{(1473K)} = $ **5.1L**

$T_1 = 1473K$ $T_2 = 298K$

3) I have 130 liters of gas in a piston at a temperature of 250^0 C. If I cool the gas until the volume decreases to 85 liters, what will temperature of the gas be?

$V_1 = 130L$ $V_2 = 85L$ $T_2 = \frac{V_2T_1}{V_1}$ $\frac{(85L)(523K)}{(130L)} = $ **340 K**

$T_1 = 523K$ $T_2 = X$

Gay-Lussac Law Worksheet $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

1) Determine the pressure change when a constant volume of gas at 1.00 atm is heated from 20.0 °C to 30.0 °C.

$P_1 = 1 atm \quad P_2 = x$

$T_1 = 293 K \quad T_2 = 303 K$

$P_2 = \frac{P_1 T_2}{T_1} \quad \frac{(1 atm)(303 K)}{(293 K)} = \boxed{1.03 atm}$

2) A container of gas is initially at 0.500 atm and 25 °C. What will the pressure be at 125 °C?

$P_1 = 0.500 atm \quad P_2 = X$

$T_1 = 298 K \quad T_2 = 398 K$

$P_2 = \frac{P_1 T_2}{T_1} \quad \frac{(0.500 atm)(398 K)}{(298 K)} = \boxed{0.67 atm}$

3) A gas container is initially at 47 mm Hg and 77 K (liquid nitrogen temperature.) What will the pressure be when the container warms up to room temperature of 25 °C?

$P_1 = 47 mmHg \quad P_2 = X$

$T_1 = 77 K \quad T_2 = 298 K$

$P_2 = \frac{P_1 T_2}{T_1} \quad \frac{(47 mmHg)(298 K)}{(77 K)} = \boxed{180 mmHg}$

4) A gas thermometer measures temperature by measuring the pressure of a gas inside the fixed volume container. A thermometer reads a pressure of 248 Torr at 0 °C. What is the temperature when the thermometer reads a pressure of 345 Torr?

$P_1 = 248 torr \quad P_2 = 345 Torr$

$T_1 = 273 K \quad T_2 = X$

$T_2 = \frac{P_2 T_1}{P_1} \quad \frac{(345 torr)(273 K)}{(248 Torr)} = \boxed{380.}$

Combined Gas Law Worksheet $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

1) If I initially have 4.0 L of a gas at a pressure of 1.1 atm, what will the volume be if I increase the pressure to 3.4 atm?

$P_1 = 1.1 atm \quad P_2 = 3.4 atm$

$V_1 = 4.0 L \quad V_2 = X$

$V_2 = \frac{P_1 V_1}{P_2} \quad \frac{(1.1 atm)(4.0 L)}{3.4 atm} = \boxed{1.2 L}$

2) A toy balloon has an internal pressure of 1.05 atm and a volume of 5.0 L. If the temperature where the balloon is released is 20^0 C, what will happen to the volume when the balloon rises to an altitude where the pressure is 0.65 atm and the temperature is -15^0 C?

$P_1 = 1.05 atm \quad P_2 = 0.65 atm$

$V_1 = 5.0 L \quad V_2 = X$

$T_1 = 293 K \quad T_2 = 258 K$

$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2}$

$\frac{(1.05 atm)(5.0 L)(258 K)}{(293 K)(0.65 atm)} = \boxed{7.1 L}$

3) A small research submarine with a volume of 1.2×10^5 L has an internal pressure of 1.0 atm and an internal temperature of 15^0 C. If the submarine descends to a depth where the pressure is 150 atm and the temperature is 3^0 C, what will the volume of the gas inside be if the hull of the submarine breaks?

$P_1 =$ $P_2 =$

$V_1 =$ $V_2 =$

$T_1 =$ $T_2 =$

4) People who are angry sometimes say that they feel as if they'll explode. If a calm person with a lung capacity of 3.5 liters and a body temperature of 36^0 C gets angry, what will the volume of the person's lungs be if their temperature rises to 39^0 C. Based on this, do you think it's likely they will explode?

Ideal Gas Law Worksheet

1) How many moles of gas does it take to occupy 120 liters at a pressure of 2.3 atmospheres and a temperature of 340 K?

$PV = nRT \quad n = \frac{PV}{RT} \quad \left(\frac{2.3\,atm}{}\right)\left(\frac{120\,L}{1}\right)\left(\frac{K \cdot mol}{0.0821\,L\,atm}\right)\left(\frac{1}{340\,K}\right) = 9.9$ moles

2) If I have a 50 liter container that holds 45 moles of gas at a temperature of 200^0 C, what is the pressure inside the container?

$PV = nRT \quad P = \frac{nRT}{V} \quad (45\,mol)\left(\frac{0.0821\,L\,atm}{K \cdot mol}\right)\left(\frac{473\,K}{1}\right)\left(\frac{1}{50\,L}\right) = 35$ atm

3) It is not safe to put aerosol canisters in a campfire, because the pressure inside the canisters gets very high and they can explode. If I have a 1.0 liter canister that holds 2 moles of gas, and the campfire temperature is 1400^0 C, what is the pressure inside the canister?

4) I have a balloon that can hold 100 liters of air. If I blow up this balloon with 3 moles of oxygen gas at a pressure of 1 atmosphere, what is the temperature of the balloon?

5) 10) 1.089 g of a gas occupies 4.50 L at 20.5 °C and 0.890 atm. What is its molar mass?

$PV = \frac{m}{M}RT$ $M = \frac{mRT}{PV}$ $\left(\frac{1.089g}{1}\right)\left(\frac{0.0821 L \cdot atm}{K \cdot mol}\right)\left(\frac{293.5K}{1}\right)\left(\frac{1}{0.890 atm}\right)\left(\frac{1}{4.5L}\right) = 6.55 \frac{g}{mol}$

6) A chemist has synthesized a greenish-yellow gaseous compound of chlorine and oxygen, and measures its density as 7.71 g/L at 36oC and 2.88 atm. Find the molarbmass and chemical formula of this compound?

$PV = \frac{m}{M}RT$

$PM = \frac{m}{V}RT$

$PM = DRT$

$M = \frac{DRT}{P}$ $\frac{7.71g}{L}$ $\frac{0.0821 L \cdot atm}{K \cdot mol}$ $\frac{309K}{1}$ $\frac{1}{2.88 atm}$ = 67.9g

ClO_2

Gas Stoichiometry Problems

1. If 3.80g of sodium metal is allowed to react to completion with excess water at STP, how many liters of hydrogen gas will be produced if it has 100% yield? $2Na + 2H_2O \rightarrow 2NaOH + H_2$

$3.80g\ Na \left(\frac{1 mol}{22.99g}\right)\left(\frac{1 mol H_2}{2 mol Na}\right)\left(\frac{22.4L}{1 mol H_2}\right) = 1.85\ L\ H_2$

2. If 12.2g Calcium metal is allowed to react with excess hydrochloric acid, determine the volume of hydrogen gas produced at 1.00 atm pressure and 18°C. $Ca + 2HCl \rightarrow CaCl_2 + H_2$

$PV = nRT$

$V = \frac{nRT}{P}$ $12.2g\ Ca \left(\frac{1 mol Ca}{40.08g}\right)\left(\frac{1 mol H_2}{1 mol Ca}\right)\left(\frac{0.0821 L \cdot atm}{K \cdot mol}\right)\left(\frac{291K}{1}\right)\left(\frac{1}{1 atm}\right) = 7.3 L$

3. Determine the volume of oxygen gas at 27°C and 0.821 atm produced by decomposition of 2.44g potassium chlorate.

4. What volume of hydrogen gas is produced by the reaction of 15.0g aluminum with excess hydrochloric acid at 27°C and 680 torr.

3) What's the partial pressure of carbon dioxide in a container that holds 5 moles of carbon dioxide, 3 moles of nitrogen, and 1 mole of hydrogen and has a total pressure of 1.05 atm?

Graham's Law of Effusion Worksheet

1. In an experiment, it takes an unknown gas 1.5 times longer to diffuse than the same amount of oxygen gas, O_2. Find the molar mass of the unknown gas.

O

2. What is the ratio of the rates of diffusion of hydrogen gas to ethane gas, C_2H_6?

$$\frac{rate_A}{rate_B} = \frac{\sqrt{molar\ mass_B}}{\sqrt{molar\ mass_A}} \qquad \frac{rate_{H_2}}{rate_{C_2H_6}} = \frac{\sqrt{30.08}}{\sqrt{2.02}} = 3.86$$

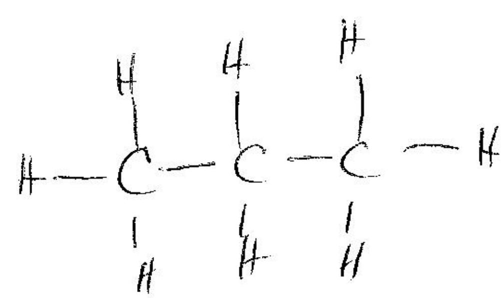
Hydrogen diffuses 3.86 times faster than C_2H_6

3. Suppose you have a sample of gas A, with a molar mass of 75 g/mol, and another sample of gas B, with a molar mass of 150 g/mol. How many more times faster will gas A diffuse than gas B?

$$\frac{\sqrt{150}}{\sqrt{75}} = 1.4 \text{ times faster.}$$

4. Methane (CH_4) diffuses 1.66 times faster than another alkane (simplest straight chained carbon hydrogen compounds containing only single bonds). What is the mass of the unknown alkane? Can you predict the formula if you know that the compound contains 3 carbon atoms?

$$\frac{1.66^2}{1} = \frac{(\sqrt{x})^2}{(\sqrt{16.05})^2}$$



$$2.7556 = \frac{x}{16.05} \qquad x = 44.$$

$C \times 3 = 36g$
$H \times 8 = 8$
44 g

C_3H_8

5. How many grams of zinc must be dissolved in sulfuric acid in order to obtain 600mL of hydrogen gas at 20°C and 770 torr? (Assume 100% yield)

$PV = nRT \quad n = \frac{PV}{RT}$ $\quad Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

$\left(\frac{770\ torr}{1}\right)\left(\frac{0.6\ L}{1}\right)\left(\frac{K \cdot mol}{62.4\ L \cdot torr}\right)\left(\frac{1}{293\ K}\right)\left(\frac{1\ mol\ Zn}{1\ mol\ H_2}\right)\left(\frac{65.41\ g}{1\ mol\ Zn}\right) = 1.7 \approx$ 2 g Zn

6. Given the reaction that gaseous carbon monoxide reacts with oxygen gas to produce carbon dioxide. What volume of carbon dioxide at standard condition can be produced from 112g carbon monoxide and 48g oxygen gas?

Dalton's Law of Partial Pressures Worksheet

1) If I place 3 moles of N_2 and 4 moles of O_2 in a 35 L container at a temperature of 25^0 C, what will the pressure of the resulting mixture of gases be?

2) Two flasks are connected with a stopcock. The first flask has a volume of 5 liters and contains nitrogen gas at a pressure of 0.75 atm. The second flask has a volume of 8 L and contains oxygen gas at a pressure of 1.25 atm. When the stopcock between the flasks is opened and the gases are free to mix, what will the pressure be in the resulting mixture?

$P_T = P_1 + P_2 + P_3$ If the total pressure of a mixture (A,B,C) of 3 gases is 2.7 atm and gas A has a partial pressure of 50. mmHg and Gas B has a partial pressure of 150 Kpa what is the partial pressure of gas C in atm?

$2.7\ atm - \left(50\ mmHg\left(\frac{1\ atm}{760\ mmHg}\right)\right) - \left(150\ kPa\left(\frac{1\ atm}{101.3\ kPa}\right)\right) = 1.2\ atm$ for C